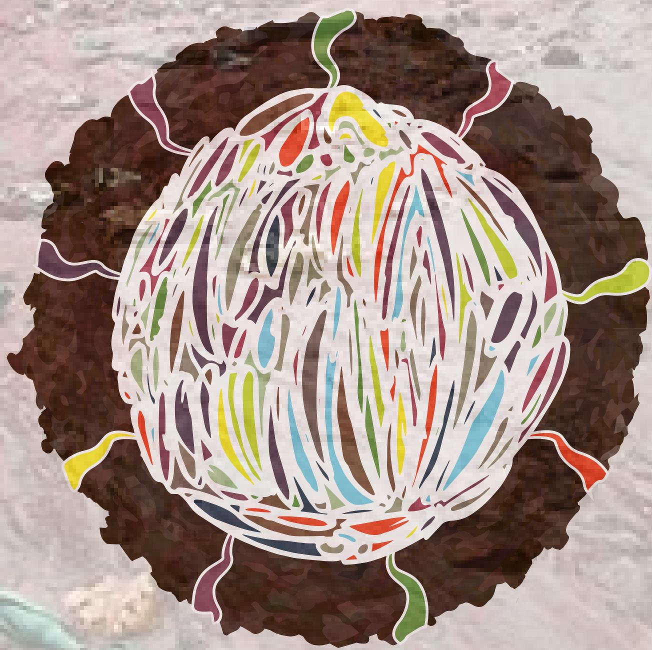
Food and Agriculture Organization of the United Nations

BE THE SOLUTION TO SOIL POLLUTION

GLOBAL SYMPOSIUM ON SOIL POLLUTION

PROCEEDINGS



2 - 4 MAY 2018 | FAO - ROME, ITALY

GLOBAL SOIL PARTNERSHIP
itps INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS
World Health Organization
UN environment
STOCKHOLM CONVENTION
ROTTERDAM CONVENTION
BASEL CONVENTION

allowing value contamination of irrigation water, irrigated ground and agricultural plants by heavy metals; methods of improvement of quality and optimization of irrigation waters composition, that is reached in the process of their acids, calcium amelioration and actions on reduction of arrival of heavy metals in plants. The designed criterion's and the indexes of quality have refilled normative basis of process ecologization of irrigation agriculture and receiving of non-polluting agricultural commodity in Ukraine. The main conclusions should be summarized here, and can also include recommendations or suggest application of the results beyond the study.

References

Baliuk, S.A., Vorotyntseva, L.I. & Ladnykh, V.Ya. 2014. Measures to detoxify contaminated soils and reduce the translocation of heavy metals to crops. Recommendations. Kharkiv: Smuzhasta Typography Ltd. 56 p. (ukr.)

Baliuk, S.A., Medvedev, V.V. & Miroshnychenko M.M. (eds). 2015. National Program of Soil Protection of Ukraine Kharkiv, 59 p. (ukr.)

FAO. 2015. Revised World Soil Charter, *FAO*.Available at: http://www.fao.org/3/a-i4965e.pdf[accessed 14.02.18]

1.1.12. Long term organochlorine soil pollution in agriculture: The lessons learnt from the Chlordecone pollution in French West Indies

Magalie Lesueur Jannoyer[1], Philippe Cattan[2], Charles Mottes[1], Florence Clostre[1], Pauline Della Rossa[1], Thierry Woignier[3]

[1]CIRAD, jannoyer@cirad.fr, MUSE and HortSys Research unit, Montpellier and Lamentin, France and Martinique
[2]CIRAD, cattan@cirad.fr, MUSE and GECO Research Unit, Montpellier, France
[3]CNRS –IRD, woignier@imbe.fr, Imbe Research Unit, Lamentin, Martinique

---

Abstract

The French West Indies face nowadays a diffuse and long term environmental pollution related to historical use of organochlorine insecticide in banana fields, Chlordecone (CLD). Due to its stability, it now pollutes soil, waters, agricultural products and leads to a global exposure of people and ecosystems. We wonder how to manage such a complex pollution system involving all environmental compartments, linked each other.

For that, we have been conducting research studies for more than 15 years in the field of agronomy and environment to explore the fate of the molecule in the environment, the impact on food safety, and also the remediation options. Three main points are addressed: i) how to characterize the pollution and to make easier the diagnosis? ii) how to assess the impacts on environmental compartments and agricultural products? iii) How to manage the pollution?

The tools we developed make a diagnosis of such pollution easier at different scales (field, farm, watershed, and territory). We built monitoring support systems for the water quality of rivers with models helping to understand variability of water contamination. We built also decision support systems to farmers to manage their soil pollution and choose the crops that will ensure food security. Now CLD content of local crop products on the market complies with the Maximum Residue Limit. Management is more complex for animal products, and further investigations are needed.

We investigated alternative solution to enhance CLD soil sequestration, using physical properties of French West Indies volcanic soil and organic matter amendment. Increased organic matter content in soil reduced drastically the CLD transfer from soil to water, but this effect was not perennial and amendment had to be regularly applied.

Our results show that an integrative approach is needed to build efficient policies to manage such pollution than to prevent new ones.

Keywords: soil and water pollutions, food safety, population exposure, decision support tools.

Introduction, scope and main objectives

Chlordecone (CLD) is an organochlorine molecule used in agriculture to fight against banana black weevil from the 70's to the beginning of 90's in Guadeloupe and Martinique (French West Indies). It has been applied as a powder around banana tree. Because of its poor solubility, its high affinity to organic matter and its high stability, CLD has been accumulated into soil compartment during around 20 years, inducing a long term and diffuse environmental pollution (Lesueur Jannoyer *et al.*, 2016). Now, it is polluting soil, waters, agricultural products and leads to a global exposure of people and ecosystems. Thus it led to a public health issue (Multigner *et al.*, 2016; ANSES, 2017).

Our team worked for more than 15 years in the field of environment and agronomy, to better understand CLD fate in the environment (diffusion, accumulation) and provide decision and support tools to manage the pollution, and ensure food safety. We worked at the border of various scientific disciplines. Our aim was to elaborate a holistic approach taking into account the different scales relevant for the pollution monitoring and management. Our aim was to answer some basic questions such as where is the pollution, what are the levels of CLD content in the environmental compartments, for how long the pollution will be observed and will impact the environment, and finally how to manage the pollution for soil, water, crops and animals to reduce the global population exposure to the pollutant?

We present here a set of work to illustrate the complexity of processes, levers and constrain to elaborate an efficient management and also the necessity to gather a wide range of disciplines to tackle all the mentioned above issues (Lesueur Jannoyer *et al.*, 2016). The objective here is to demonstrate how all these works contributed to the global management of CLD pollution and how they could be useful in the management of other agricultural pollution or prevent such situation.

Methodology

We developed specific tools according to the scale and the management objectives, with related publications for each of them, aiming to characterize the pollution state of the environmental compartments and the processes determining transfer between them.

To assess the field mean CLD content, we applied specific sampling methods and simulated the optimal sampling grid and number of samples at the field scale (Clostre *et al.*, 2014). We also studied the effect of ploughing on the CLD pollution profile in soils, analyzing the CLD content in the top soil layer (0-30cm) and in the soil horizon B (30-60 cm).

To assess the water CLD content and its spatial and temporal variations, we elaborated a monitoring system at the watershed scale and modelled the CLD transfers (Mottes *et al.*, 2016). Using spatial statics, we simulated the spatial contribution of polluted fields to the river pollution and put forward the river pollution profile (Della Rossa *et al.*, 2016). This kind of work was useful to identify where the pollution was coming from and where to take priority management measures.

To assess the crop contamination, we analyzed the relationship between soil and plant CLD content as well as the contamination of different organs (root, stem, leaf, fruit) for different type of crops (root and tubers, cucurbits, salads, fruits, vegetable) (Clostre *et al.*, 2017). We also measured the capacity of absorption and the time exposure and contamination relationship for animals, especially poultry (Jondreville *et al.,* 2013).

As biological (Chaussonnerie *et al.*, 2016) and chemical (Legeay *et al.*, 2017) degradation was not efficient enough in our field conditions (anoxic conditions *vs* soil for agriculture), we thought about an alternative to enhance CLD soil sequestration. We tested the trapping effect of volcanic soil clays, allophane and halloysite, with the addition of 10% organic matter in soil and analyzing the CLD content in the soil water solution (Woignier *et al.*, 2013).

Results

To assess the mean CLD content in the soil of a plot, we proposed a systematic sampling grid, with at least 20 samples a plot (Clostre *et al.*, 2014) and 2 depths (0-30 cm and 30-60 cm). Soil pollution depends on the frequency and the depth of ploughing. Field with no tillage led to high superficial soil pollution, while deeply and frequently ploughed field led to the pollution of deep soil layers, with reduced/diluted CLD content. Modelling demonstrated that only slow transfer from soil to water was naturally occurring (Cabidoche, pers com) and more than one to five hundred years were needed, according to the soil type, to achieve depollution this way.

To assess and simulate the CLD content in the water of a river along time and according field location and practices, we used the WATPPASS model (Mottes *et al.*, 2015) at the watershed scale. We demonstrated that the CLD content in river was quite constant around year with a slight increase during dry period (Crabit *et al.*, 2016). This reflects that the main pathway for CLD transfer from soil to river was underground flow rather than surface transport (Charlier *et al.*, 2009; Mottes *et al.*, 2017). At the watershed scale, we also showed that whatever the plot location, the plot was contributing to the river pollution, and thus all polluted fields have to be considered to manage river pollution. CLD content in river varies also along the flow, with increasing values when crossing soil polluted area i.e. historical fields of banana. In the case of the Galion basin with polluted area mid-stream, this leads the CLD river profile to increase from upstream to mid-stream and to decrease from midstream to downstream (Della Rossa *et al.*, 2016).

To assess the crop contamination, we surveyed crops according to the soil CLD content, the field soil type and the type of crop. We identified three types of behavior for crops: roots and tubers that are very sensitive to contamination; cucurbits, sugar cane and salads that can transfer CLD to stem, leaves and fruits from a certain level of CLD soil pollution; and non-sensitive crops such as banana, fruit trees, pineapple and Solanaceae that are free of CLD whatever the soil pollution. We also elaborate a conceptual model of CLD transfer from soil to plant. A passive transfer and decreasing gradient was observed from soil solution, root, stem, leave and fruit. For root and tuber, direct contact of the pollutant on the peel was also accounting for the CLD contamination, with a higher CLD content in the peel (Clostre *et al.*, 2015). We built a support system for farmers to help them choosing their crops according to the soil CLD content of their field and ensuring to fit with the regulation with crop CLD content under the Maximum Residue Limit (20µg/kg Fresh Matter) (Clostre *et al.*, 2017).

The management of animal contamination is more complex because first animals, as well as people, concentrate the CLD molecule in their body and second the farm practices led them to move from a field to another. Their CLD exposure comes mainly from the consumption of polluted soil and water. For example, poultry has a very efficient capacity to extract CLD from soil when they eat soil particle (Jondreville *et al.*, 2013). Thus even when the soil is slightly polluted, hens and eggs are highly contaminated. Animals have also the capacity to excrete CLD, but decontamination time is not realistic for poultry and livestock raising/animal husbandry constrains.

We also thought about depollution but, since nowadays biological and chemical solutions are not operational, we tested alternative option such as sequestration. Tropical volcanic soils have physical properties that allow sequestrating high amount of Carbon and pollutant. We thus combined the CLD chemical affinity for organic matter and the structure and property of allophane clays to trap the pollutant (Woignier *et al.*, 2013). The addition of organic matter in soil reduce CLD leaching and increase the trapping effect, but the process is not a long term one and organic matter has to be re-added on the field (Woignier *et al.*, 2016).

Discussion

The different tools, soil sampling grid and depth of soil sampling, support decision for crop choice, are now used by framers, government services and authorities. Many of the management and sanitary recommendations are based upon our results: sampling, peeling generously the root and tuber, avoiding polluted soil contact for household poultry … For more than 8 years, the majority of crops comply with the regulation with no marketed crop product over the MRL. But household products still expose people to CLD (ANSES, 2017), and deeper analysis is needed to adapt recommendations.

If now the situation of CLD pollution is quite well characterized, management is still an issue as pollution will persist and cross disciplines approaches are needed in the field of environment, agriculture and public health.

Conclusions

Our work tackled a complex and long term environmental pollution due to agricultural use of pesticides years ago. Thanks to focused efforts and interdisciplinary approach, we built numerous tools and supports systems to assess, monitor and manage CLD pollution. However, further studies are still needed to deepen the comprehension of transfer and degradation processes to improve remediation and depollution. Specific efforts are to be made to coordinate actions and elaborate a consistent management plan.

We built an expertise on this kind of diffuse and long term pollution. We applied our tools to simulate the fate and pressure of other pesticides used nowadays in agriculture. We wish this kind of approach and support systems could be useful to prevent such environmental pollution.

Acknowledgements

We thank the CAEC technical teams from Cirad and IRD that helped us for the field trials and the crop, water and soil samples collection, the laboratories that made the chlordecone analysis (LDA26 and LDA972). Our work has been funded by the Chlordecone National Action Plan, the Water Office of Martinique, the French National Research Agency (Chlordexco project), the French Ministry of Over Seas and the European FEDER funds of Martinique (GIT project).

References

ANSES. 2017, Exposure of Antillean consumers to chlordecone, results from the Kannari study (in French): 202 pp. Available at https://www.anses.fr/fr/system/files/ERCA2014SA0109Ra.pdf [accessed 08.02.18]

Chaussonnerie, S., Saaidi, P.L., Ugarte, E., Barbance, A., Fossey, A., Barbe, V., Gyapay, G., Brüls, T., Chevallier, M., Couturat, L., Fouteau, S., Muselet, D., Pateau, E., Cohen, G.N., Fonknechten, N., Weissenbach, J. & Le Paslier, D. 2016. Microbial Degradation of a Recalcitrant Pesticide: Chlordecone. *Front Microbiol*. 7: 2025. doi: 10.3389/fmicb.2016.02025

Clostre, F., Lesueur Jannoyer, M., Achard, R., Letourmy, P., Cabidoche, Y.M. & Cattan, P. 2014. Decision support tool for soil sampling of heterogeneous pesticide (chlordecone) pollution. *Environmental Science and Pollution Research*, 21 (3): 1980-1992. doi: 10.1007/s11356-013-2095-x

Charlier, J.-B., Cattan, P., Voltz, M. & Moussa, R. 2009. "Transport of a Nematicide in Surface and Groundwaters in a Tropical Volcanic Catchment. *J Environ Qual* 38 (3): 1031–41. Doi: 10.2134/jeq2008.0355.

Clostre, F., Letourmy, P. & Lesueur Jannoyer, M. 2015. Organochlorine (chlordecone) uptake by root vegetables. *Chemosphere*. 118: 96-102.

Clostre, F., Letourmy, P. & Lesueur Jannoyer, M. 2017. Soil thresholds and decision tool to manage food safety of crops grown in chlordecone polluted soil. *Environmental Pollution*, doi : 10.1016/j.envpol.2017.01.032

Crabit, A., Cattan, P., Colin, F. & Voltz, M. 2016. Soil and River Contamination Patterns of Chlordecone in a Tropical Volcanic Catchment in the French West Indies (Guadeloupe). *Environmental Pollution* 212 : 615–26. https://doi.org/10.1016/j.envpol.2016.02.055.

Della Rossa, P., Lesueur Jannoyer, M., Mottes, C., Plet, J., Bazizi, A., Arnaud, L., Jestin, A., Woignier, T., Gaude, J.M. & Cattan, P. 2016. Linking current river pollution to historical pesticide use: Insights for territorial management? *Science of the Total Environment*. doi:10.1016/j.scitotenv.2016.07.065

Jondreville, C., Bouveret, C., Jannoyer Lesueur, M., Rychen, G. & Feidt, C. 2013, Relative bioavailability of tropical volcanic soil-bound chlordecone in laying hens *Gallus domesticus*), *Environmental Science and Pollution Research*, 20 (1), 292-299, doi: 10.1007/s11356-012-1010-1

Legeay, S., Billat, P.A., Clere, N., Nesslany, F., Bristeau, S., Faure, S. & Mouvet, C. 2017. Two dechlorinated chlordecone derivatives formed by in situ chemical reduction are devoid of genotoxicity and mutagenicity and have lower proangiogenic properties compared to the parent compound. E*nviron Sci Pollut Res*. doi 10.1007/s11356-017-8592-6

Lesueur Jannoyer, M., Cattan, P., Woignier, T. & Clostre, F. 2016. *Crisis management of a chronic pollution: from contaminated soil to human health impacts (the chlordecone case study)*, K26557, CRC Press, ISBN 9781498737838, 266 pp.

Mottes, C., Lesueur Jannoyer, M., Charlier, J.B., Carles, C., Guéné, M., Le Bail, M. & Malézieux, E. 2015. Hydrological and pesticide transfer modeling in a tropical volcanic watershed with the WATPPASS model. *Journal of Hydrology*, 529: 909-927. http://dx.doi.org/10.1016/j.jhydrol.2015.09.007

Mottes, C., Lesueur Jannoyer, M., Le Bail, M., Guéné, M., Carles, C. & Malézieux, E. 2017. Relationships between past and present pesticide applications and pollution at a watershed outlet: The case of a horticultural catchment in Martinique, French West Indies. *Chemosphere*. 184: 762-773. doi: 10.1016/j.chemosphere.2017.06.061

Multigner, L., Kadhel, P., Rouget, F., Blanchet, P. & Cordier, S. 2016. Chlordecone exposure and adverse effects in French West Indies populations. *Environ Sci Pollut Res Int*. 23: 3-8. doi:10.1007/s11356-015-4621-5

Woignier, T., Fernandes, P., Soler, A., Clostre, F., Carles, C., Rangon, L., Lesueur Jannoyer, M. 2013 Soil microstructure and organic matter: Keys for chlordecone sequestration. *Journal of Hazardous Material*. 262: 357-364

Woignier, T., Clostre, F., Fernandes, P., Rangon, L., Soler, A., Lesueur Jannoyer, M. 2016. Compost addition reduces porosity and chlordecone transfer in soil microstructure. *Environmental Science and Pollution Research*, 23 (1): 98-108. http://dx.doi.org/10.1007/s11356-015-5111-5